

COMBUSTION/PARTICLE SIZING EXPERIMENTS
AT THE NAVAL POSTGRADUATE SCHOOL
COMBUSTION RESEARCH LABORATORY *

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Particle behavior in combustion processes is an active research area at the Naval Postgraduate School (NPS). Currently, four research efforts are being conducted at the Combustion Research Laboratory.

There is a long standing need to better understand the soot production and consumption processes in gas turbine combustors, both from a concern for improved engine life and to minimize exhaust particulates. Soot emissions are strongly effected by fuel composition and additives. NPS efforts are directed at these two effects. Soot particles in gas turbine engines are generally quite small, typically between 0.01 and 1.0 micron. This size range is beyond present holographic capabilities and, therefore, light transmission measurements at three wavelengths and light scattering measurements at large angles (10-50°) are being used to determine mean particle sizes within a small gas turbine combustor. Probe sampling is also being employed for comparison with the optical measurements.

A more recent need for particle sizing/behavior measurements is in the combustor of a solid fuel ramjet which uses a metallized fuel. In this combustor, metallic agglomerates are formed on the surface. The agglomerates are then either swept along the surface or are ejected from the surface and follow a trajectory up through a developing turbulent boundary layer. Eventually the particles pass through a turbulent diffusion flame which is located within the boundary layer. Upon reaching the flame (or oxygen above the flame) the particles ignite and continue to burn as they pass down the port of the motor. Predictions of the fuel regression rate and the combustion efficiency are both dependent upon a good understanding of the behavior of the particles throughout their lifetimes. Currently, high speed motion pictures are being used to study these rather large (20-500 microns) burning particles. Holographic studies are planned within the current year.

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In solid propellant rocket motors, metals (typically aluminum) are used to improve specific impulse and/or to provide damping for combustion pressure oscillations. The size of the particles vary from approximately 0.5 to 200 microns, depending upon the combustion region being studied and the propellant properties and motor operating environment. The smaller (less than 2 microns) sizes are generally not of primary interest. Although they produce primary exhaust smoke, they do not contribute significantly to two-phase flow losses in the exhaust nozzle or to losses in combustion efficiency. It is important to know the size distributions of the particles (and how the sizes change with location) if accurate predictions of combustion efficiency, particle damping, and two-phase flow losses are to be made. The particles within the motor generally are not moving too rapidly and are of large enough size to permit holographic investigations. However, the high number density of burning particles generally requires the use of diffuse illumination in the scene beam and specialized apparatus to permit penetration of the combustion zone. Both two-dimensional and three-dimensional motors are currently used together with a pulse ruby laser/holocamera. Within the exhaust nozzle velocities become quite high and particle size can rapidly decrease due to high shear stresses. In this region particle sizing experiments are being conducted using diode arrays to measure the light intensity as a function of scattering angle.

Being able to obtain good quality holograms within the solid propellant rocket motor environment is one task. However, once this is attained, a need exists for obtaining the particle size distributions from the holograms in a reasonable period of time. Automatic or semi-automatic data retrieval methods are mandatory, but complicated by the presence of speckle and nonuniform light intensity in the reconstructed holograms. NPS efforts in this area are currently based on the use of a Quantimet 720 Image Analyzer.